

HVOF as a Hard Chrome Replacement



Jon L. Devereaux

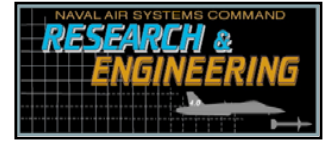
AIR - 4.3.4.1

**NADEP Jacksonville
Materials Engineer**

Report Documentation Page				Form Approved OMB No. 0704-0188	
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HVOF as a Hard Chrome Replacement



Current Status of P-3 Main Landing Gear

**HVOF MLG Piston installed 26 April 99 on VP-30
Aircraft BuNo 156522**

Aircraft completed PDM at NADEP JAX on 5 Dec 99

PDM extended due to multiple spar cap insertions

850 Landings on HVOF coated MLG Piston (Aug 00)

**HVOF Coated Piston removed from service Aug 00 due
to internal oil leak on ID-2 (NOT HVOF COATED)**

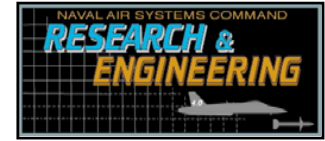
HVOF Coated Strut repaired, sent back to VP-30

Installed on Aircraft 160284 STBD April 25, 2001

1,078 Total Landings on HVOF coated strut (8/23/01)



HVOF as a Hard Chrome Replacement



Current Status of P-3 Main Landing Gear

655 Landings on HVOF coated strut since 4-25-01 (2/1/02)

1,505 Total Landings on HVOF coated strut as of 01 Feb 02

44 Landings on HVOF coated strut since 2-1-01 (9/5/02)

1,549 Total Landings on HVOF coated strut as of 5 Sept 02

584 Landings on HVOF coated strut since 9-5-02 (3/28/03)

2,133 Total Landings on HVOF coated strut as of 28 March 03

725 Landings on HVOF coated strut since 3-28-03 (9/30/03)

2,858 Total Landings on HVOF coated strut as of 30 Sept 03

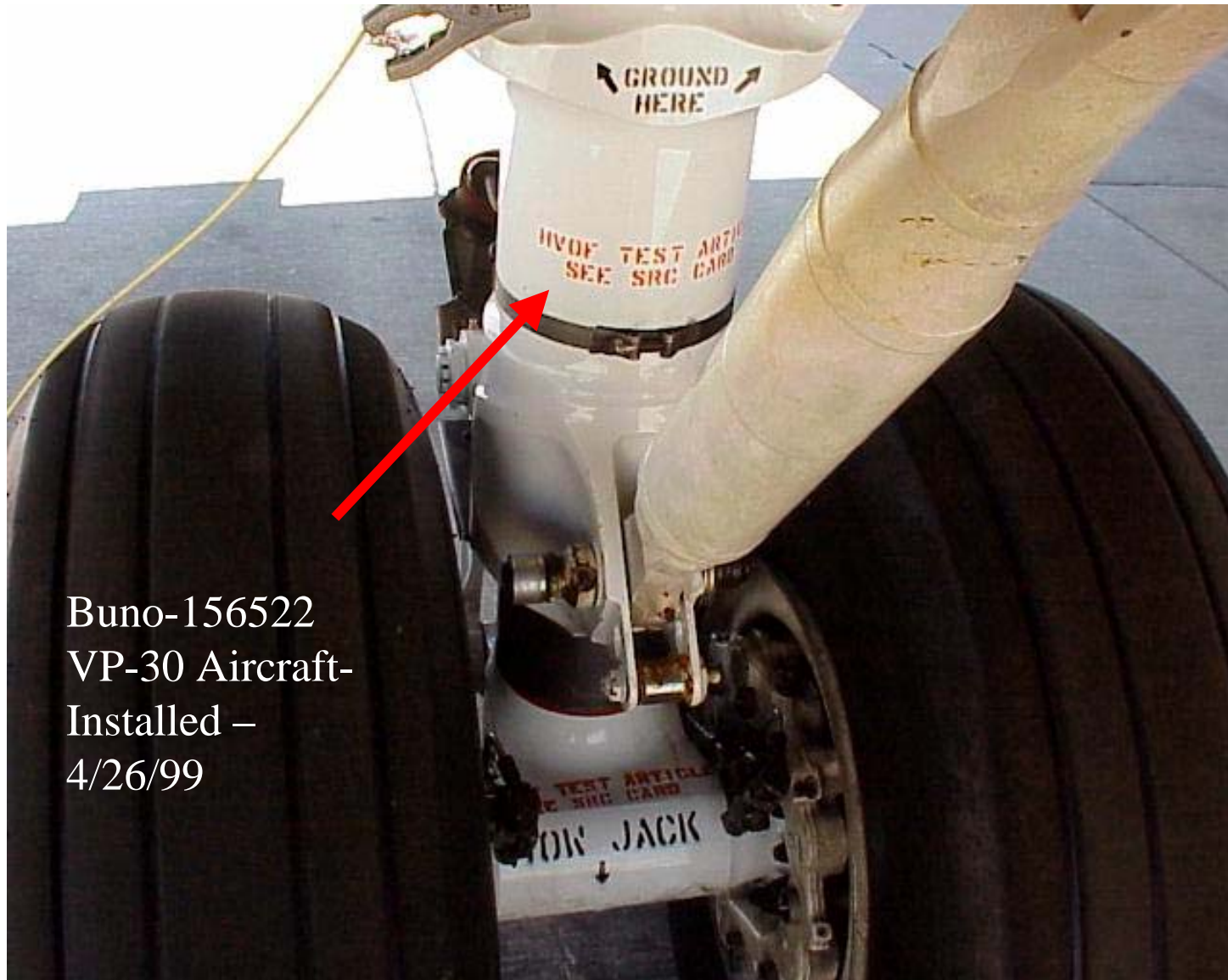
Aircraft sent to Depot JAX for PDM on 13 August 2003

HVOF as a Hard Chrome Replacement



Buno-156522
VP-30 Aircraft
Installed 4/26/99

HVOF as a Hard Chrome Replacement

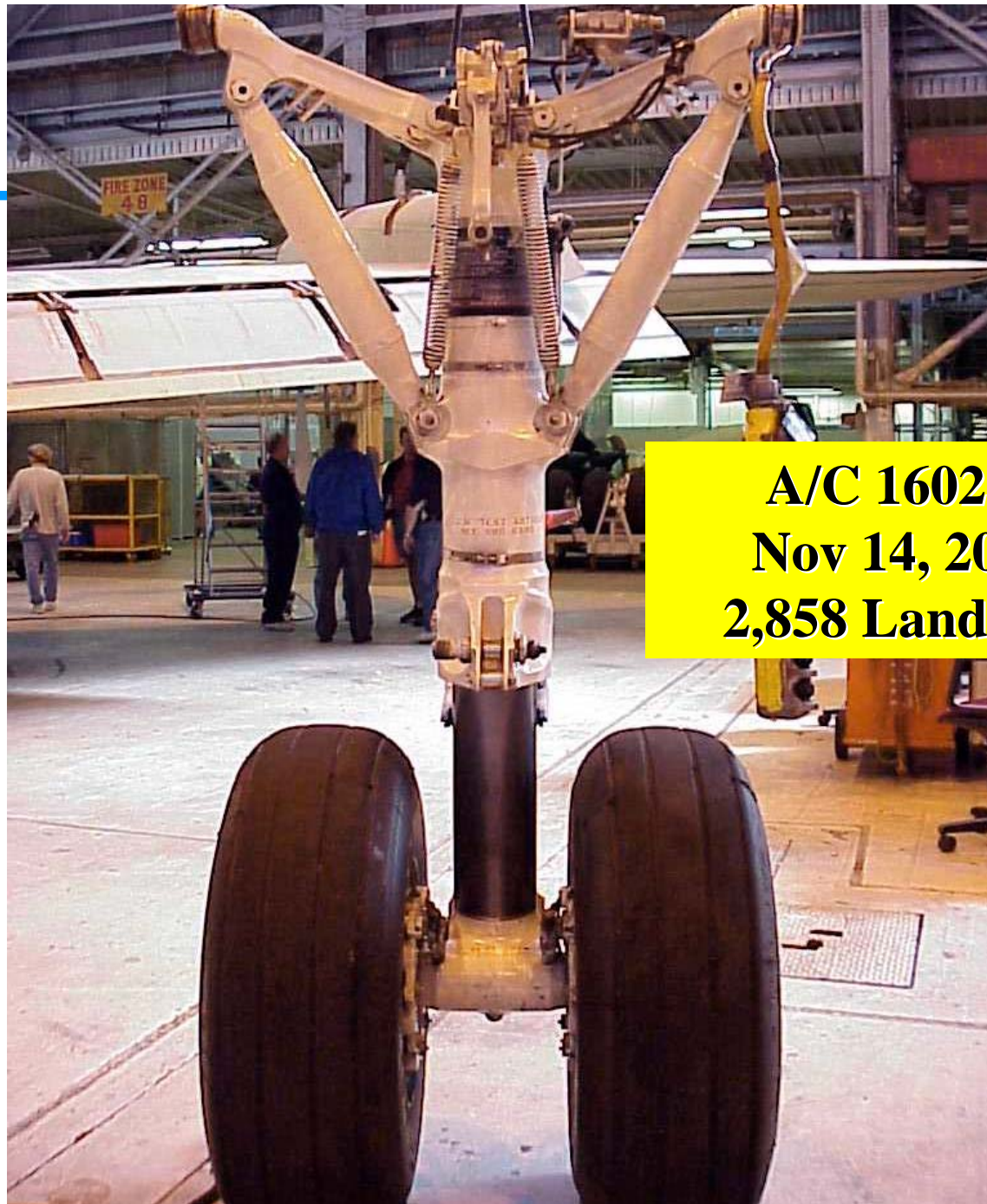


Buno-156522
VP-30 Aircraft-
Installed –
4/26/99

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A/C 160284
Nov 14, 2003
2,858 Landings





A/C 160284
Nov 14, 2003
2,858 Landings

HVOF as a Hard Chrome Replacement

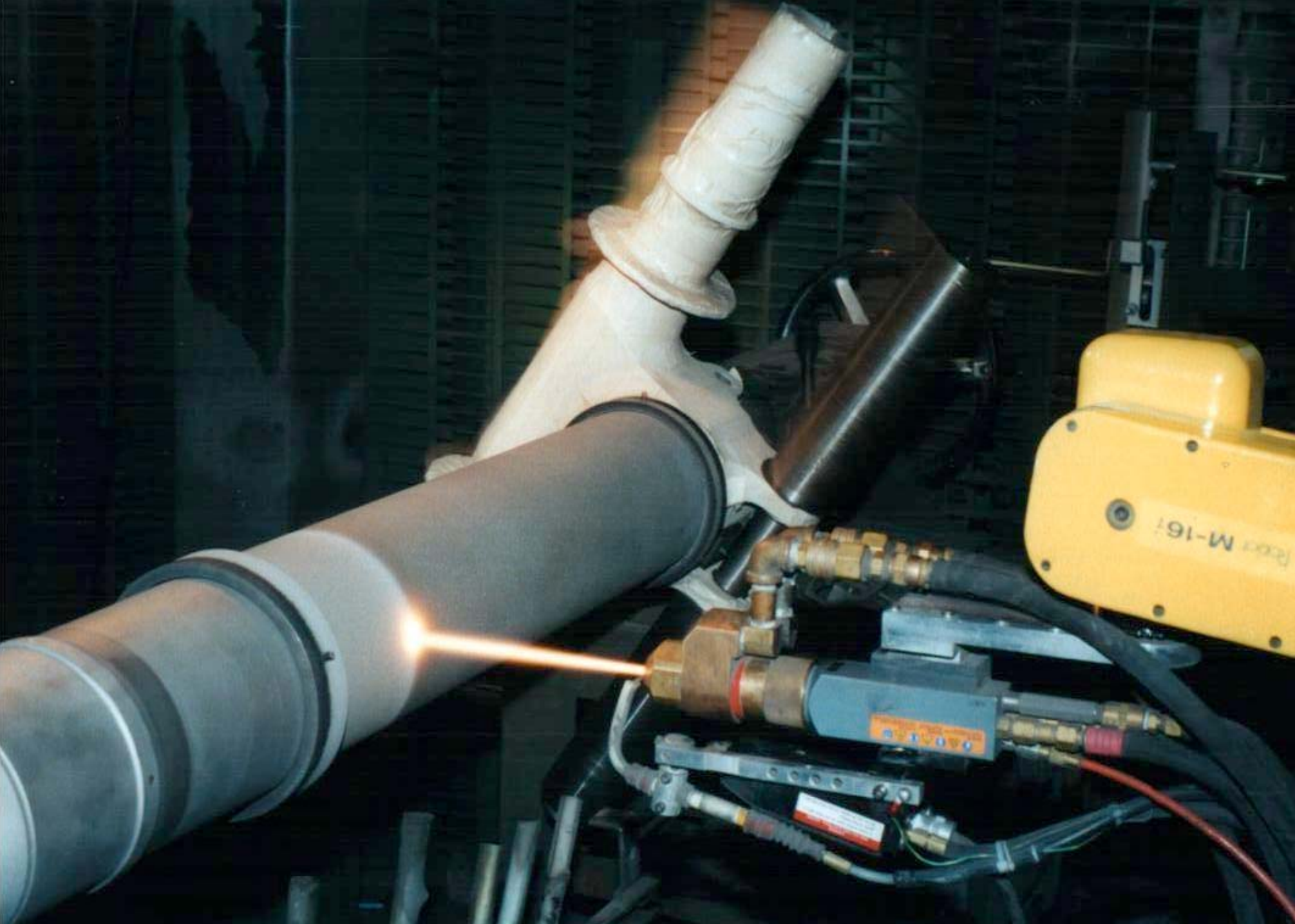
Second P-3 MLG Piston coated with HVOF WC/Co 83/17

- **To be used in \$70M P-3 aircraft SLAP/SLEP - Full Scale Fatigue Test**
- **R/H MLG chrome plated**
- **L/H MLG HVOF coated**
- **HVOF coating, grinding & processing of gear funded by Naval Research Lab (NRL)**
- **Testing started 30 August 2001 (24 month test)**
- **16,000 Cyclic Test Hrs. accumulated as of 30 Aug. 02**
- **Test down since April '02 for repairs; hope to be up Sept. 02**
- **26,000 CTH planned; ECD December 02 if all goes well**
- **Landing gear shows no sign of coating problems**

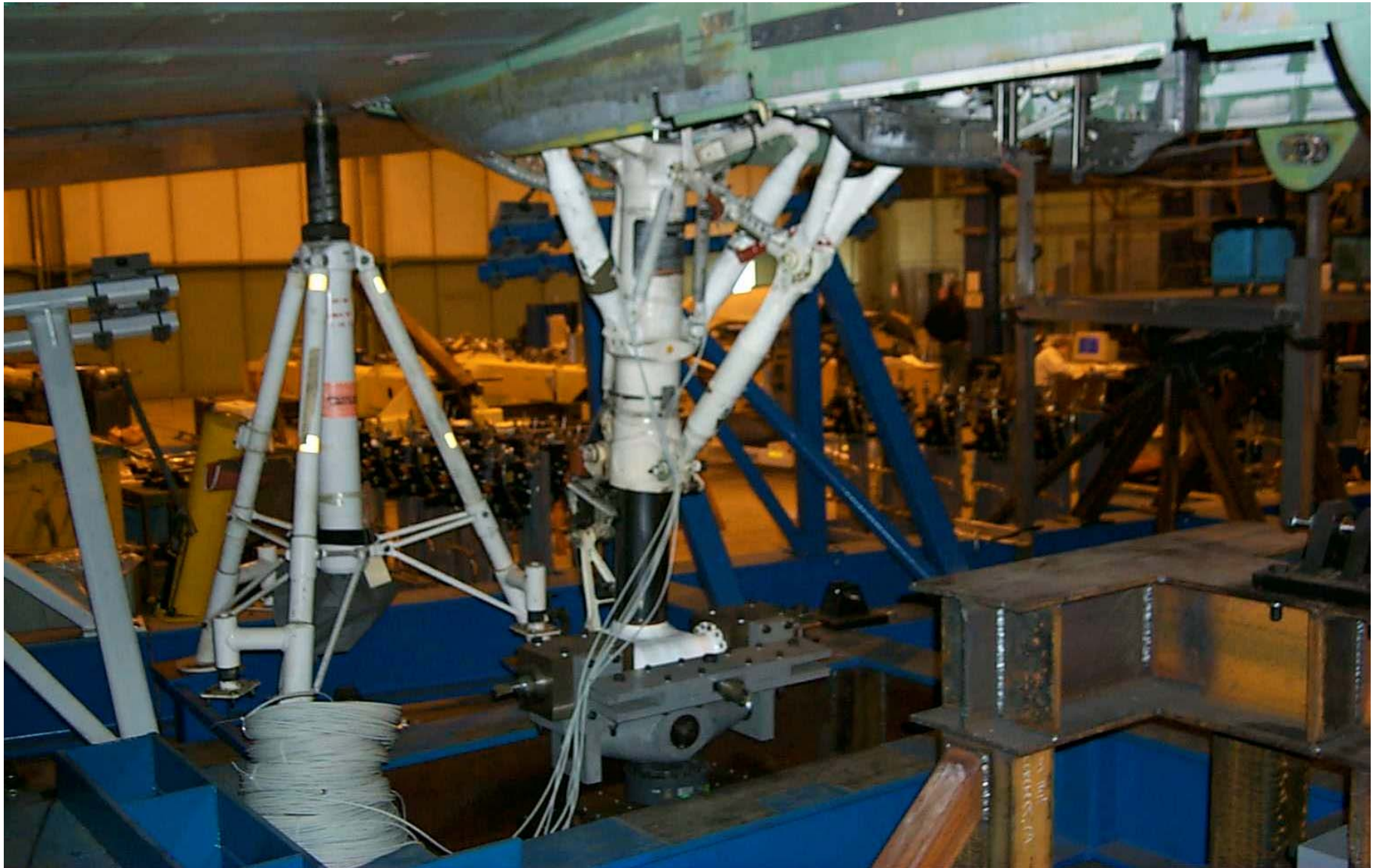
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Second P-3 MLG Piston coated with HVOF WC/Co 83/17

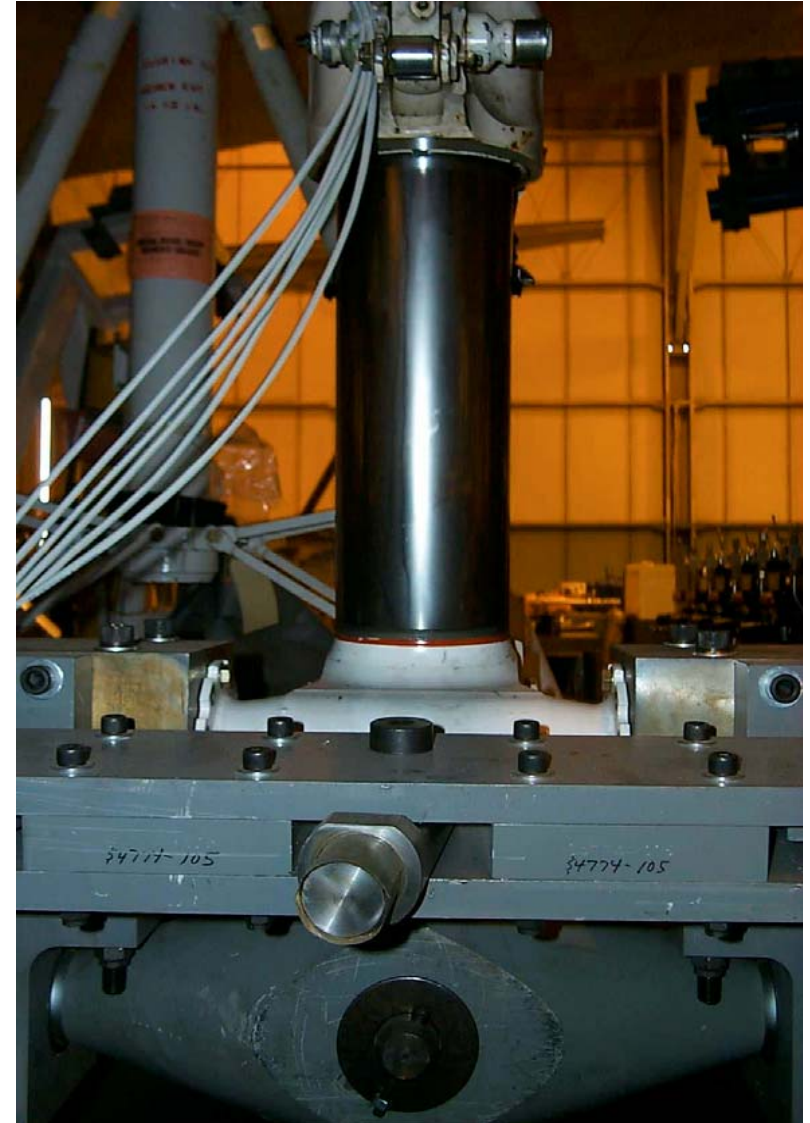
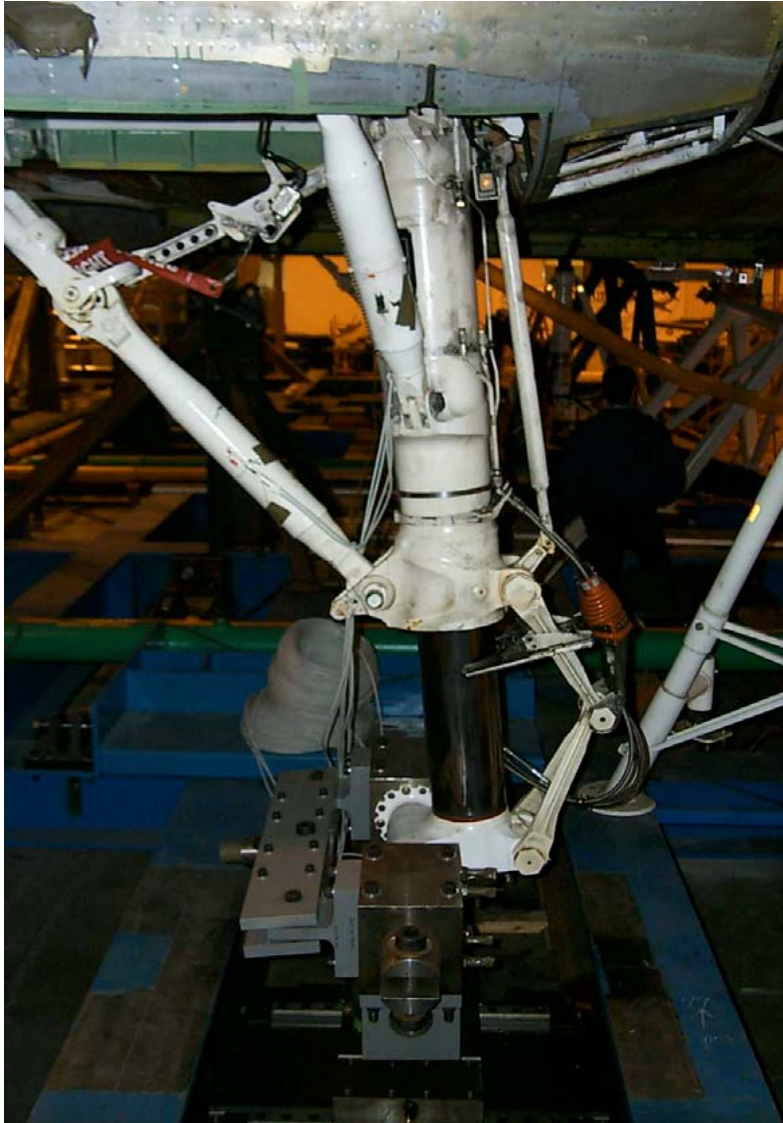
- 26,000 CTH initially planned
- Test extended to 38,000 CTH - some of airframe not tested sufficiently
- 200-250K cycles on LG representing 47,000 Landings
- Test represents two fatigue lifetimes
- If this testing doesn't break the landing gear or HVOF coating, then nothing will!
- Landing gear shows no sign of failure or coating problems
- Test Completed with a "BANG!" on 4 March 2003
- Landing Gear removed April 2003 for inspection



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HVOF as a Hard Chrome Replacement



HVOF as a Hard Chrome Replacement



HVOF as a Hard Chrome Replacement

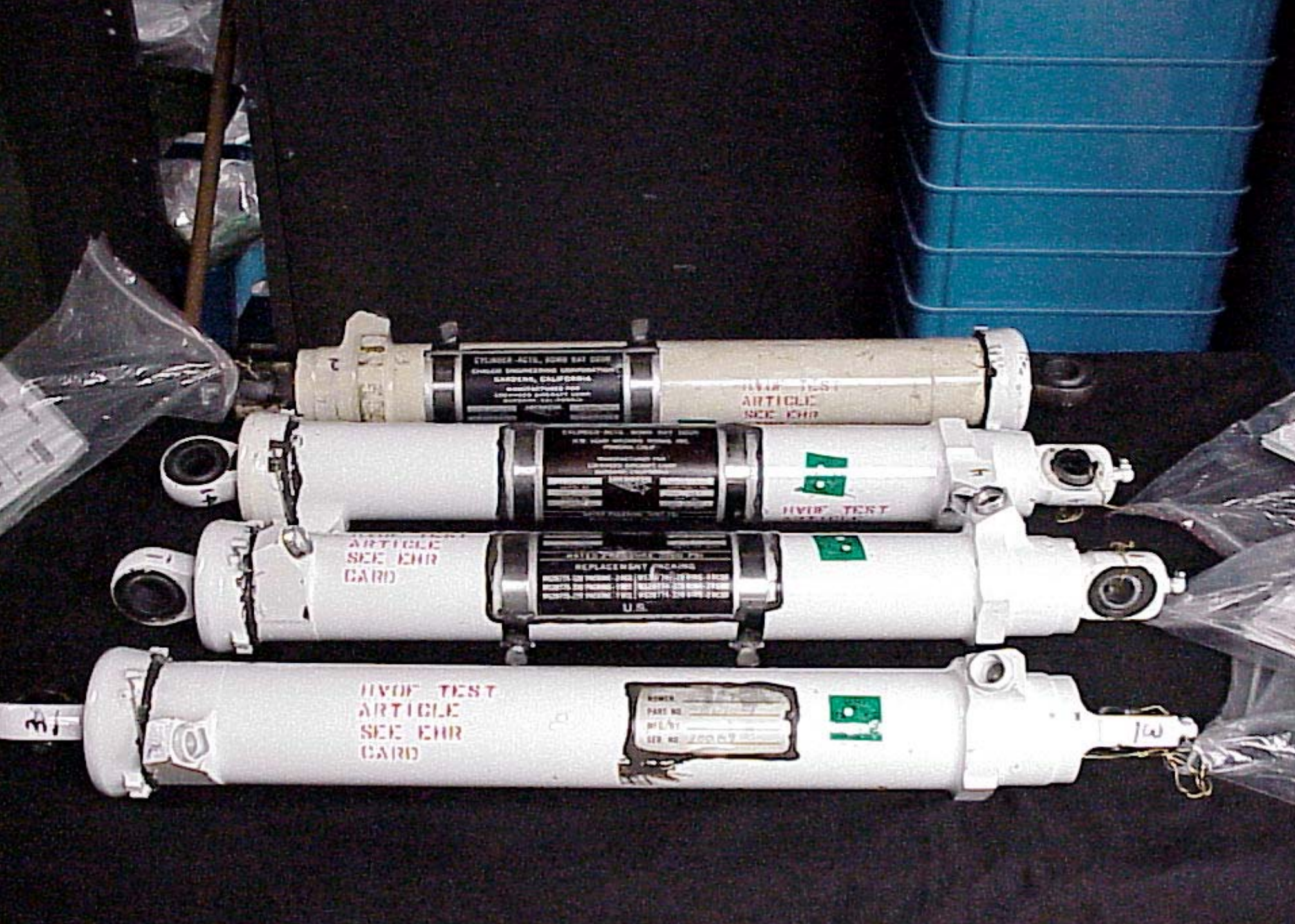


HVOF as a Hard Chrome Replacement



HVOF as a Hard Chrome Replacement

- **P-3 Bomb Bay Door Actuator Pistons coated, ground, & superfinished**
- **Four HVOF coated P-3 Bomb Bay Door Actuator Assemblies RFI and installed on VP-30 Aircraft BuNo 156510 July 2001**
- **Aircraft undergoing PDM at JAX July 2001**
- **A/C delivered back to VP-30 on 7 Sept 01**
- **91 Flight Hours on HVOF coated actuators (01 Feb 02)**
- **232 Flight Hours on HVOF coated actuators (05 Sept 02)**
- **704 Flight Hours on HVOF coated actuators (28 March 03)**
- **869 Flight Hours on HVOF coated actuators (24 Sept 03)
(Aircraft currently at Whidbey Is. for AEB 003)**



CYLINDER-ACTIL, BOMB SAT DOWN
COLUMBIA ENGINEERING LABORATORY
SACRAMENTO, CALIFORNIA
RECOMMENDATIONS FOR
LIFE-TESTS PRESENTED TO
THE U.S. AIR FORCE

HYD' TEST
ARTICLE
SEE EHR

EXPLAINED BY THE U.S. AIR FORCE
U.S. AIR FORCE
REPLACEMENT
MONTHS USE PRESENT - 2000
MONTHS USE PRESENT - 2000
MONTHS USE PRESENT - 2000
MONTHS USE PRESENT - 2000
U.S.



HYD' TEST

ARTICLE
SEE EHR
CARD

HYD' TEST
REPLACEMENT
MONTHS USE PRESENT - 2000
MONTHS USE PRESENT - 2000
MONTHS USE PRESENT - 2000
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U.S.

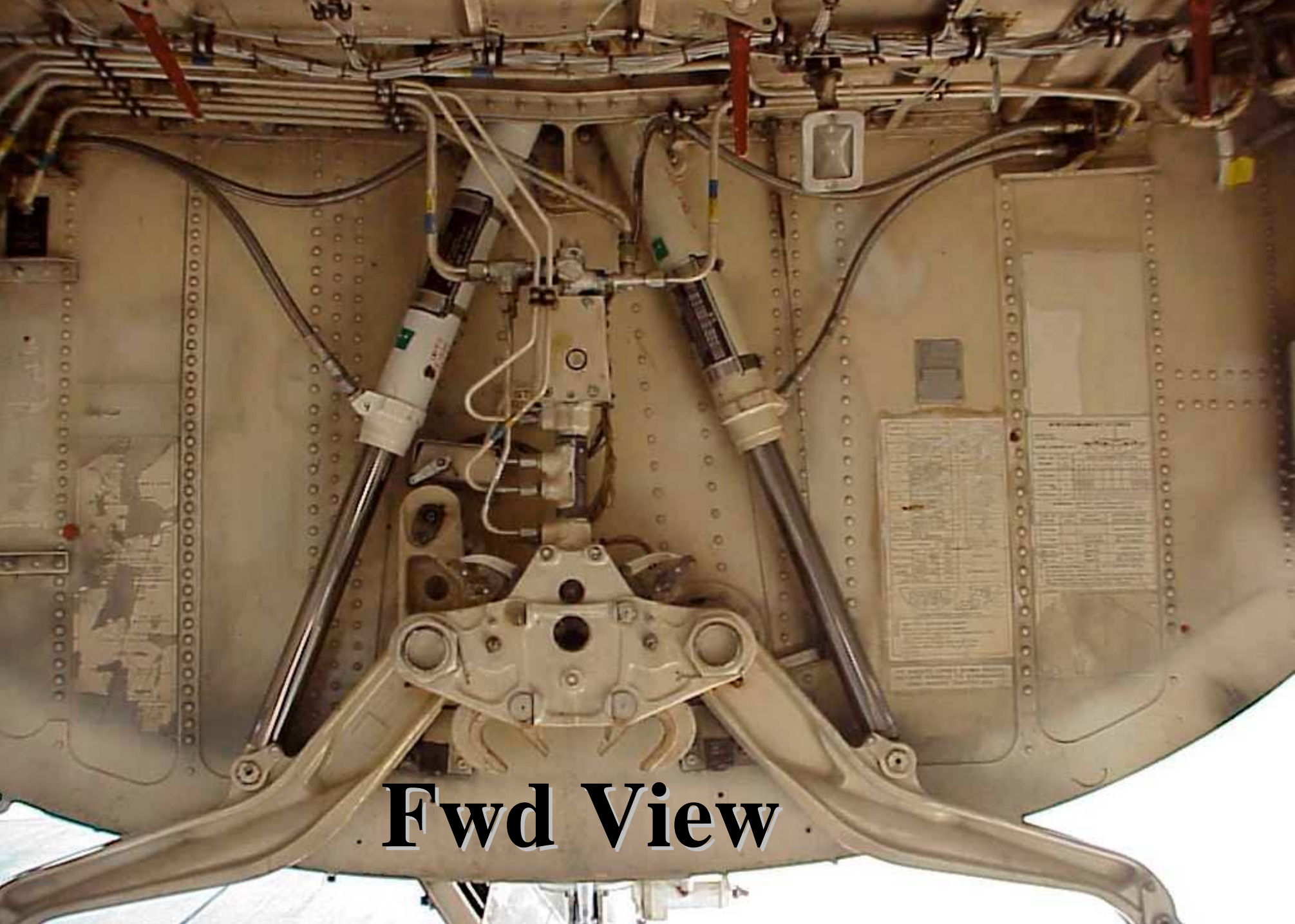


HYD' TEST
ARTICLE
SEE EHR
CARD

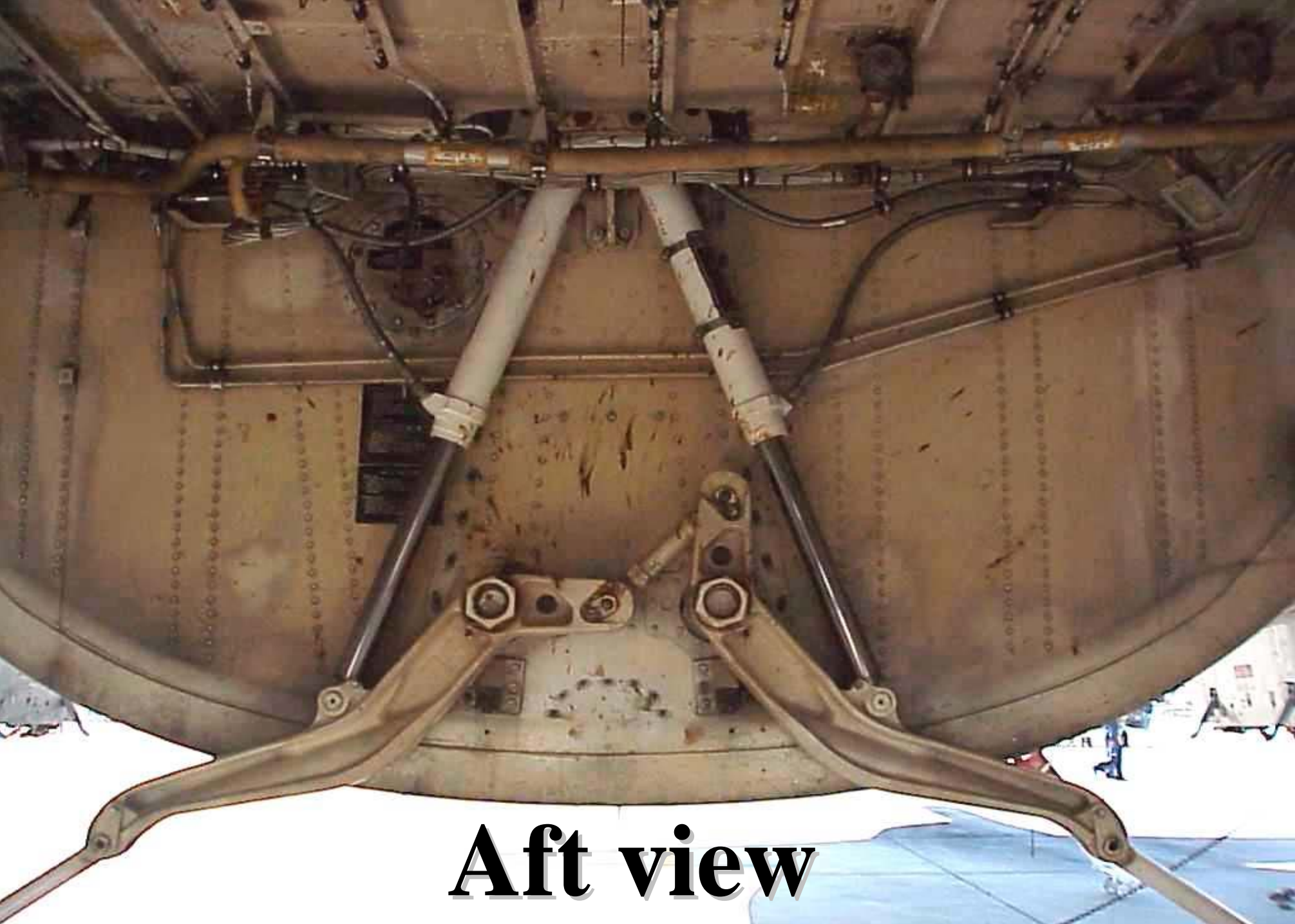
HYD' TEST
REPLACEMENT
MONTHS USE PRESENT - 2000
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MONTHS USE PRESENT - 2000
U.S.



16



Fwd View

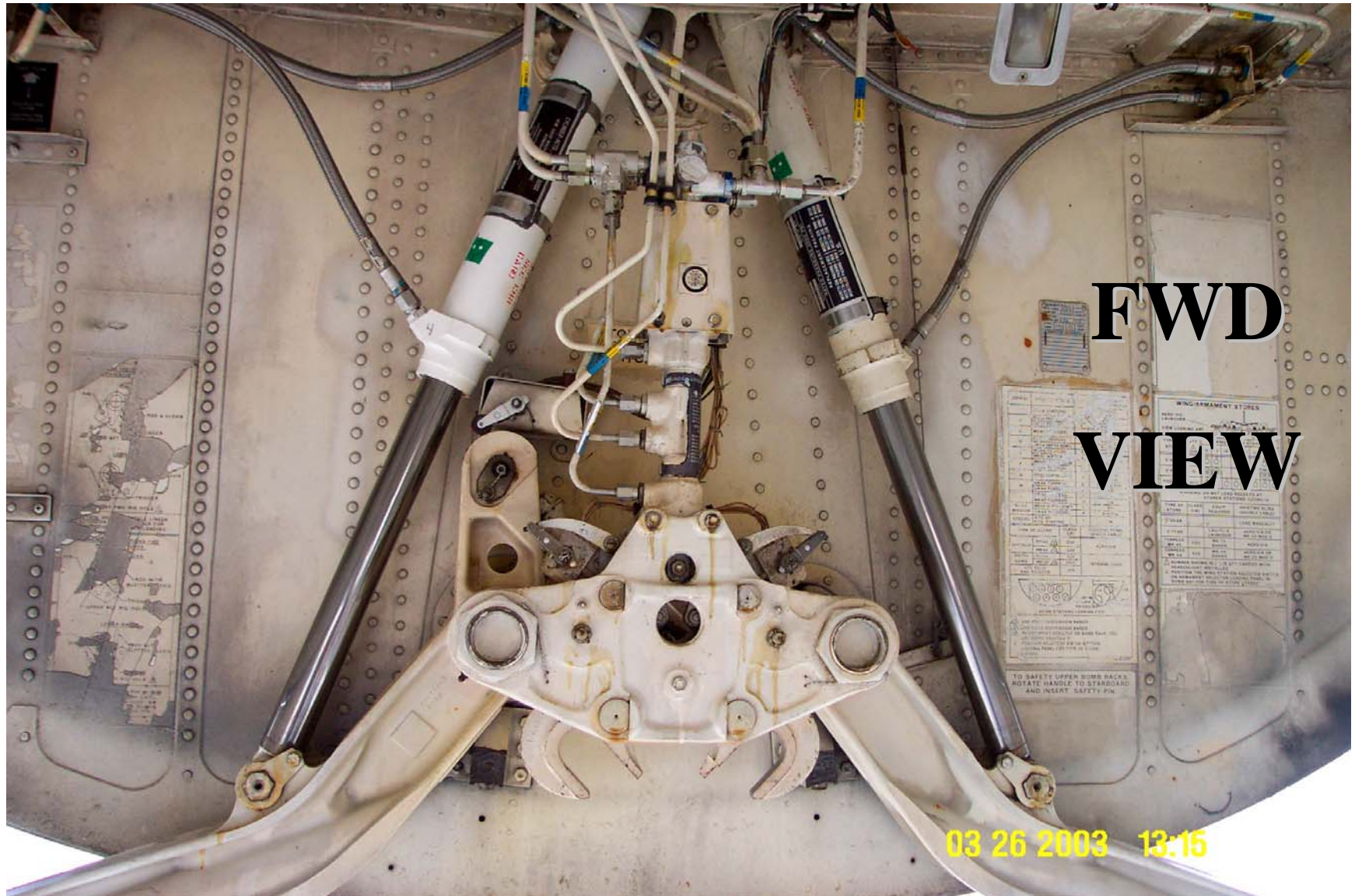


Aft view

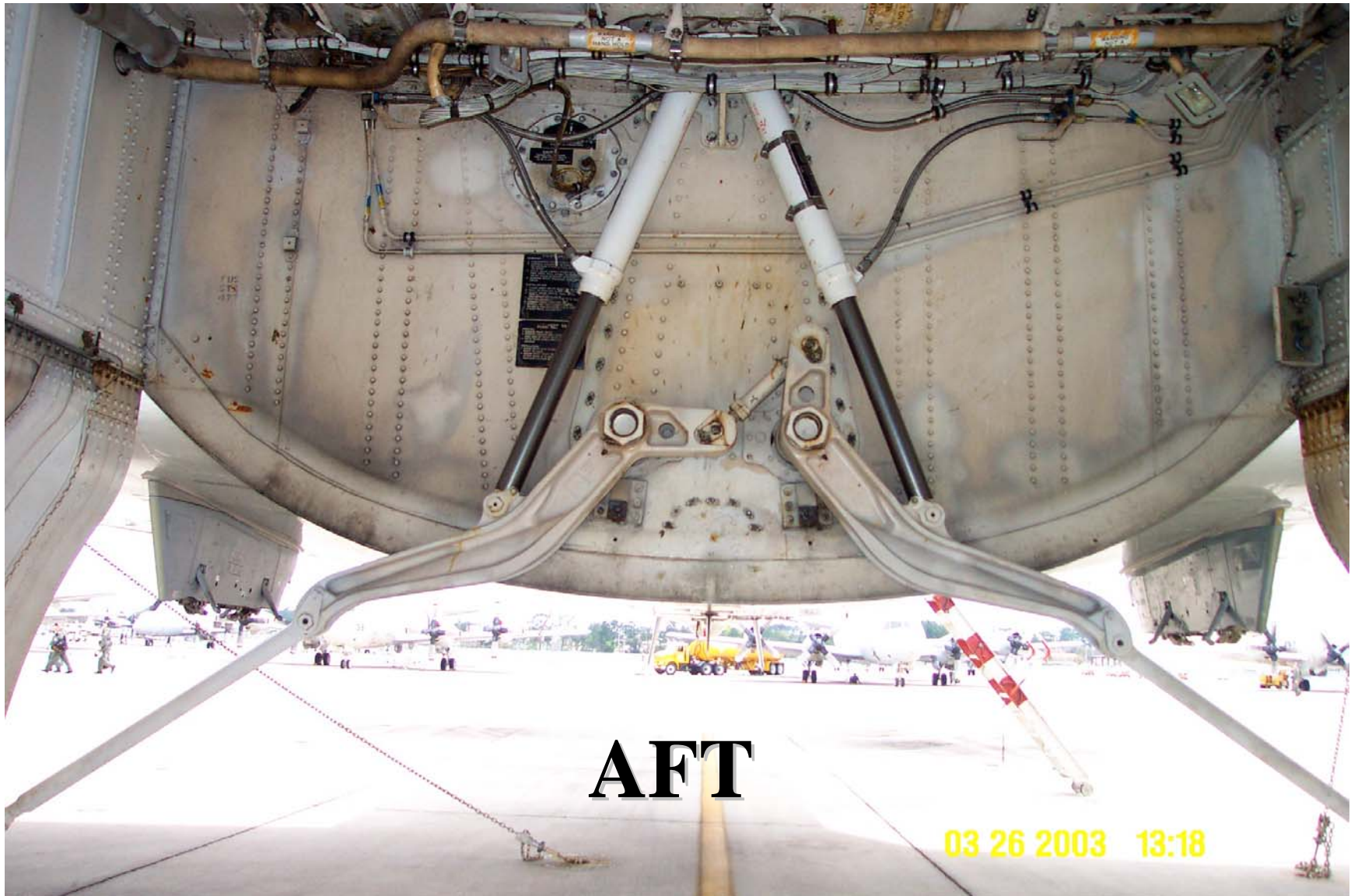
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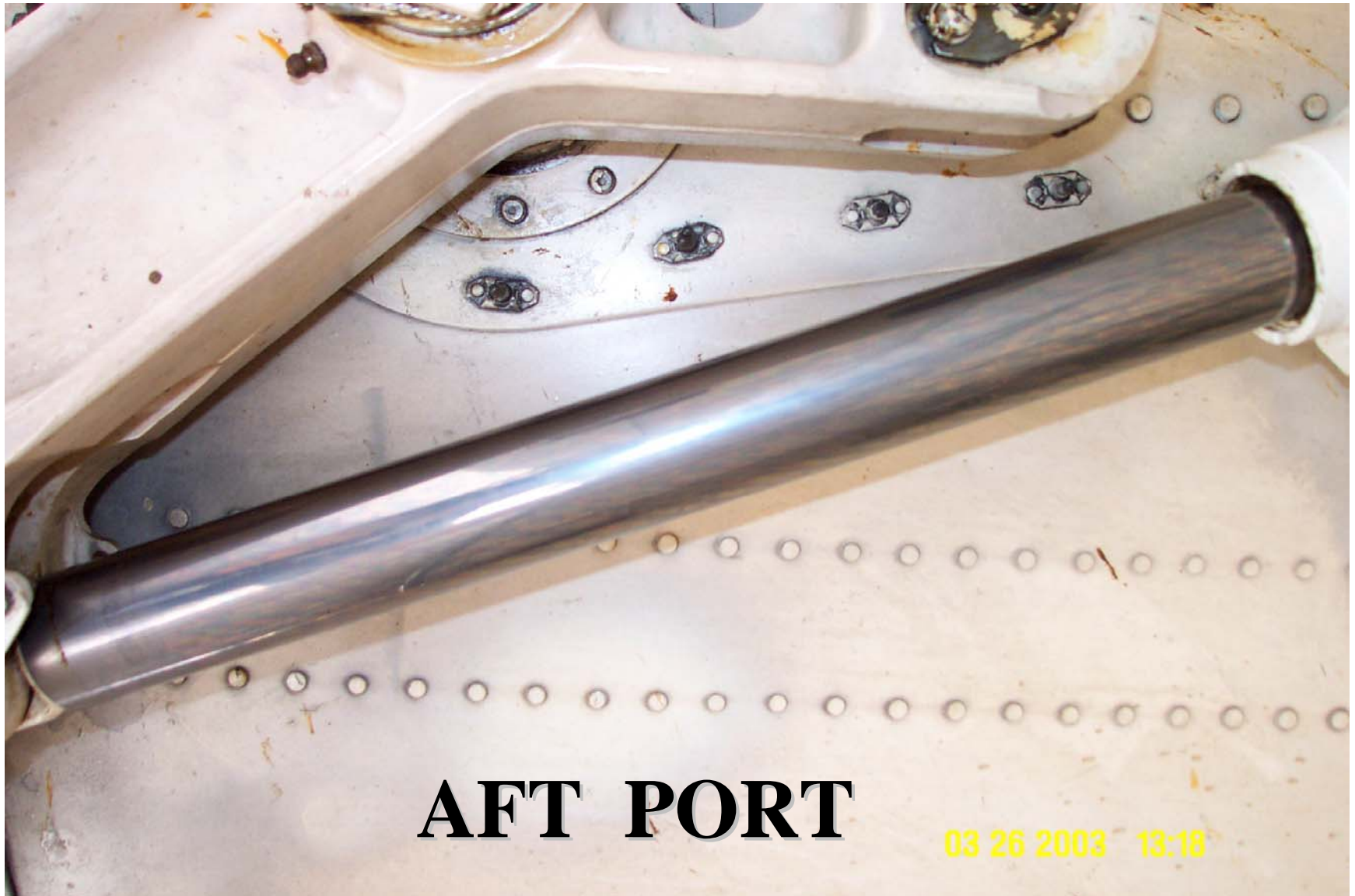
HVOF as a Hard Chrome Replacement



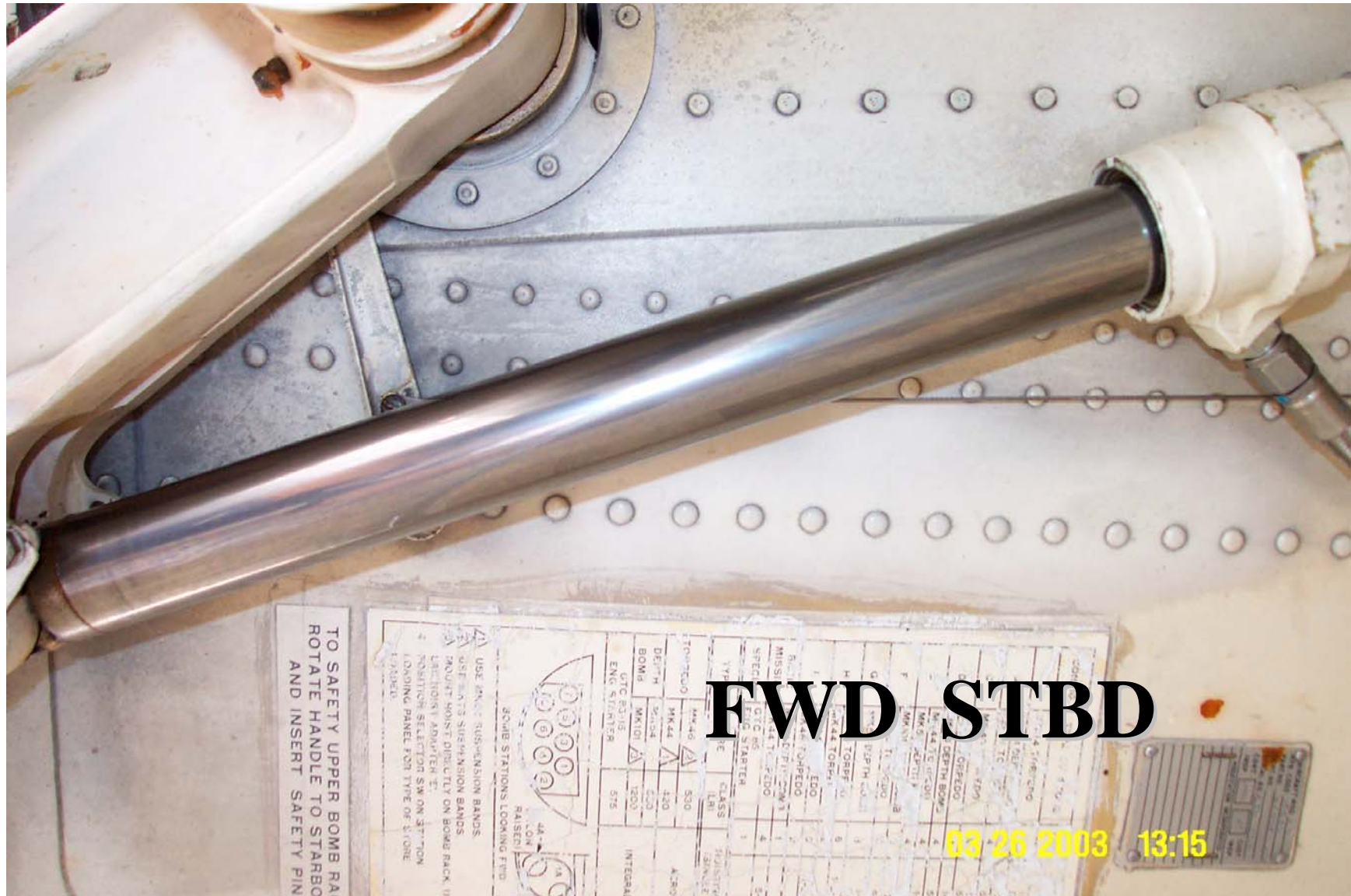
HVOF as a Hard Chrome Replacement



HVOF as a Hard Chrome Replacement

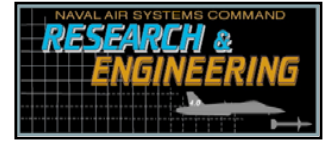


HVOF as a Hard Chrome Replacement





HVOF as a Hard Chrome Replacement



F/A-18 Horizontal Stabilator Piston Rod

P/N 3003130 (Vendor Code 93835) - Nat'l Water Lift

HVOF Coat short external end with WC/Co/Cr 86/10/4

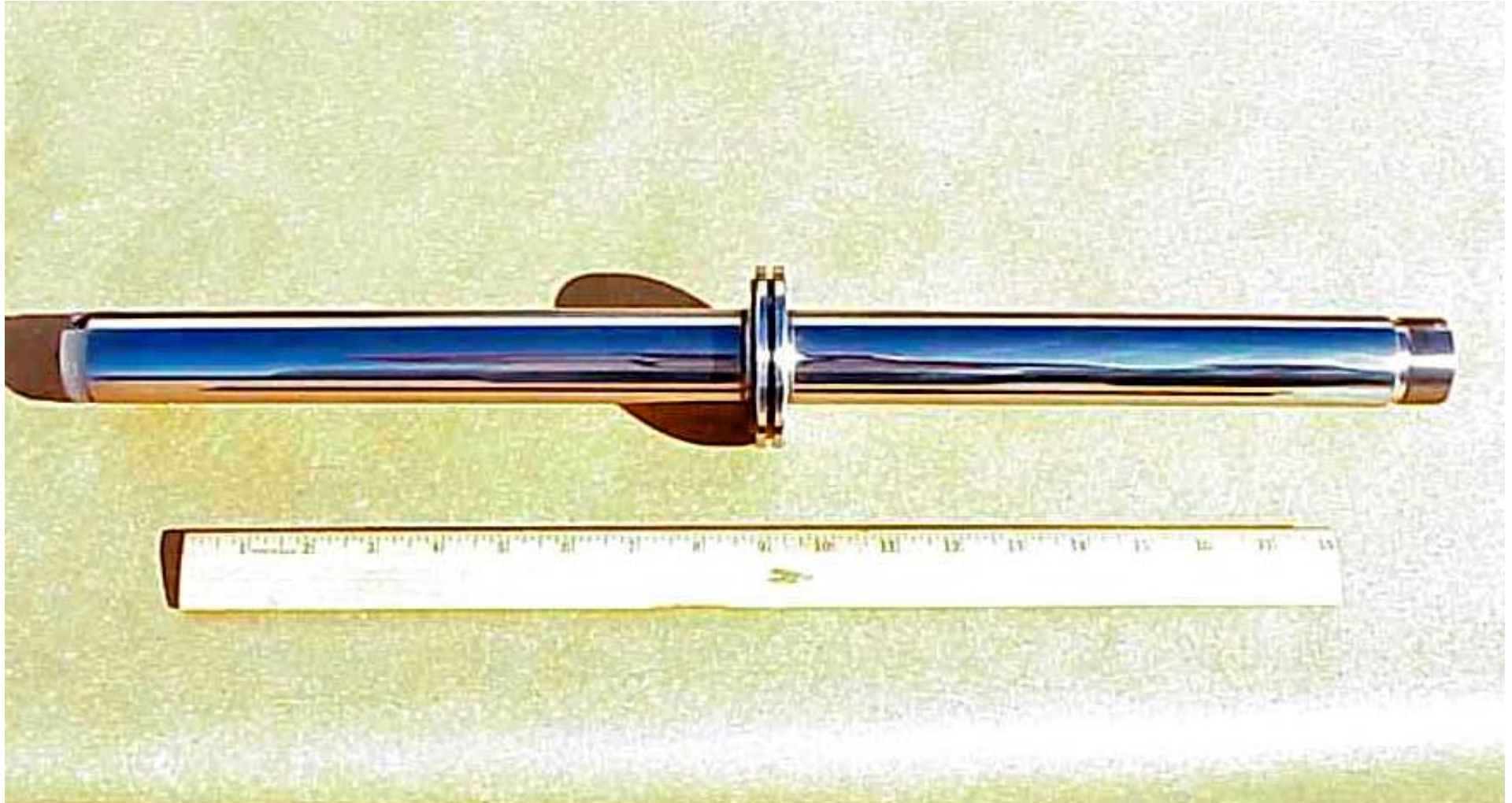
HVOF Coat longer internal end with WC/Co 83/17

Grind to 8 - 16 μ in Ra finish

Superfinish to ≤ 2 μ in Ra finish

**Shipped to PAX Lab for additional Hydraulic Actuator
seal compatibility testing on 15 Nov 02**

HVOF as a Hard Chrome Replacement



HVOF as a Hard Chrome Replacement



HVOF as a Hard Chrome Replacement

**F/A-18 Trailing Edge Flap (TEF) Actuator Piston Rod
P/N 303247-3 (Vendor Code 82106) - Parker Hannifin
HVOF Coat OD of Piston Rod with WC/Co/Cr 86/10/4**

Grind to 8 - 16 μ in Ra finish

Superfinish to ≤ 2 μ in Ra finish

**Shipped to NADEP NORIS for additional Hydraulic
Actuator seal compatibility testing on 20 Mar 03**

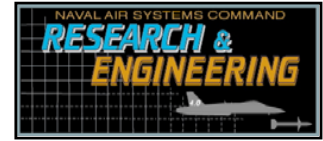
**Second F/A-18 TEF Actuator Piston Rod shipped to
NADEP NORIS 16 Sept 03 for build-up and then ship to
PAX for additional Hydraulic Actuator seal
compatibility testing**

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HVOF as a Hard Chrome Replacement



Current Status of E-6A Main Landing Gear

**Two HVOF coated E-6A MLG Uplock Hook Shafts
installed 10 March 99 on A/C 164388**

3,900.3 Flight Hours (9/01/03) A/C completed

3,116 Landings (9/01/03) Mod in Waco, TX

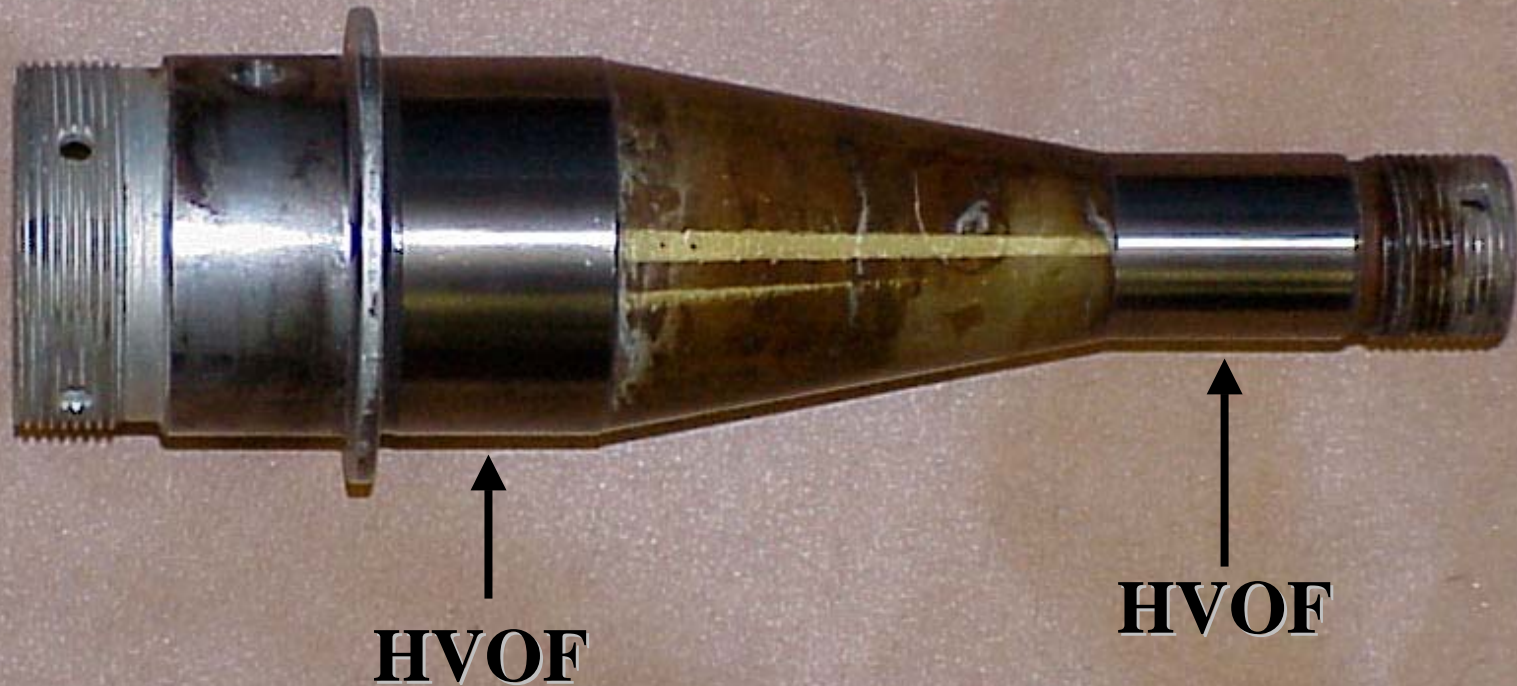
**One HVOF coated E-6A MLG Uplock Hook Shaft
installed on Aircraft 162784 in Feb. 2000**

4,223.5 Flight Hours (9/01/03)

3,020 Landings (9/01/03)

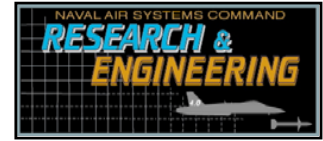
HVOF as a Hard Chrome Replacement

E-6A MLG Lock Hook Shaft P/N 9-45196





HVOF as a Hard Chrome Replacement



Current Status of HVOF Coated EA-6B Main Landing Gear Flight Clearance

MLG Collar and Piston coated Oct. 99

Components completed depot processing Dec. 99

Flight clearance requested Jan 00

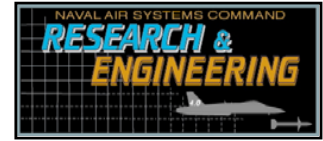
Meeting at NAVAIR/Pax River 13 April 00

Obtained NAVAIR approval of data May 00

Flight clearance at AIR 4.3.3 waiting final approval



HVOF as a Hard Chrome Replacement



“NAVAIR ONLY” HVOF L.G. meeting 16 Nov 00

Flight clearance on-hold

NAVAIR presented 240KSI requirement for all landing gear fatigue tests at Dec 00 HCAT mtg. @ KSC. Not clear where this requirement came from.

NAVAIR & NRL meeting 29 Jan 01

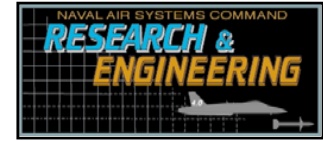
Large sample (2”-3” dia) testing discussed

NAVAIR (Eui Lee) to conduct testing

Flight clearance at AIR 4.3.3 waiting final approval



HVOF as a Hard Chrome Replacement



Meeting at BWI Sheraton 23 OCT 01

Large sample (2 1/4" OD dia) testing discussed

NAVAIR (Eui Lee) to test additional 30 large samples

Must test one NAVAIR large sample with 0.010" coating thickness at max. stress of 200 KSI, actual R-ratio of EA-6B MLG axle to be used during testing

Request to AIR 4.3.3 (Alysha Roerden) for R-ratio & max stress of EA-6B MLG inboard axle journal 23 Oct 01

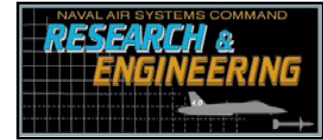
R-ratio & max. stress from AIR-4.3.3 Feb 02

(200 KSI @ R = -1)

Flight clearance at AIR 4.3.3 waiting final approval



HVOF as a Hard Chrome Replacement



Meeting at BWI Sheraton 23 OCT 2001

Large sample (2 1/4" OD dia) testing discussed

NAVAIR (Eui Lee) to test additional 30 large samples

Must test one NAVAIR large sample with 0.010" coating thickness at max. stress of 200 KSI, actual R-ratio of EA-6B MLG axle to be used during testing

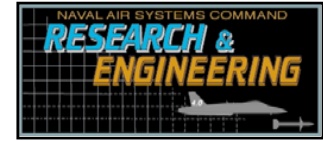
Jim Candela AIR-4.3.3 stated at the 23 Oct 01 meeting that he would accept data from either axial or bend tests

Request to AIR 4.3.3 (Alysha Roerden) for R-ratio & max stress of EA-6B MLG inboard axle journal 23 Oct 01

**R-ratio & max. stress rec'd from AIR-4.3.3 14 Feb 02
(200 KSI @ R = -1)**



HVOF as a Hard Chrome Replacement



**OEM analysis indicates max inboard journal stress for
0.010 inch thick coating is 180 KSI @ $R = +0.1$
and max inboard journal stress of 40 KSI for $R = -1$**

**Goodrich Corp., Cleveland, OH
Jack Pink (216) 429-4214, Neil Harris (216) 429-4202**

**Previously Cleveland Pneumatics - these are the people
who designed the EA-6B Landing Gear**

**EA-6B MLG alloy is 4330 V-mod
220-240 KSI UTS 180-185 KSI Yield Strength**

HVOF as a Hard Chrome Replacement

HCAT Landing Gear JTP test data for $R = +0.1$ testing of 0.003" thick coating up to 220 KSI; no spalling

Air Force A-10 NLG testing of 0.010" thick coating at $R = -0.33$ up to 260 KSI before spalling

Testing of NAVAIR large sample with 0.010" coating thickness at max. stress of 180 or 200 KSI, actual R-ratio of EA-6B MLG axle $R = +0.1$ is not necessary

NAVAIR & HCAT "big bar" tests confirmed that the stress/strain for spalling was essentially the same for both the small fatigue bar samples and the large tensile bars

AIR-4.3.3 (Candela) stated at the 23 Oct 01 meeting that he would accept data from either axial or bend tests

HVOF as a Hard Chrome Replacement

Dominant stress on the axle is bending

Bend testing done on HVOF coatings will provide more direct results than any axial testing

Axial (tension) testing on a bar does not represent the loading conditions on the axle journal

Air Force bend tests on actual A-10 NLG hardware concluded that HVOF applied WC/Co coatings 0.010" thick would remain intact at any stress level up to the yield strength of the substrate being tested

Air Force data at more severe condition of $R = -0.33$ shows 0.010" coating good up to 260 KSI

HVOF as a Hard Chrome Replacement

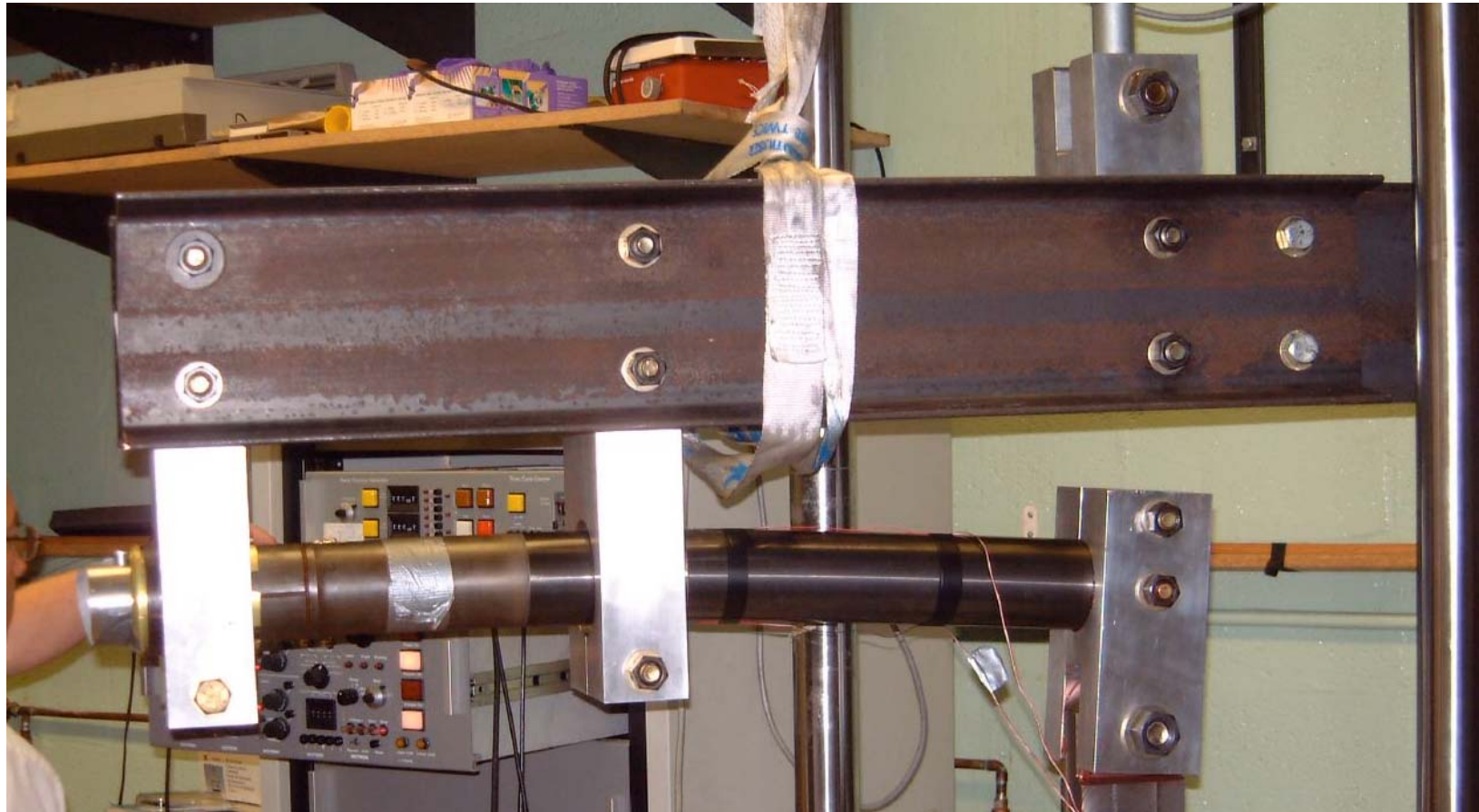
Meeting at PAX River on 19 August 2003

Discussion centered around A/F Bend Test Data. It was agreed that bend test data is more representative of the loading conditions for this application (axle journals).

OEM (Goodrich Corp. - previously Cleveland Pneumatics) presented a detailed stress analysis for the axle journals. Purpose to determine stress levels at bearing journals to aid in decision/evaluation of using HVOF on axle journals.

NAVAIR Structures (AIR-4.3.3.1) has given approval to move ahead with flight clearance request for HVOF coated Strut.

HVOF as a Hard Chrome Replacement



A-10 NLG Piston

Coating spalled at 260 KSI - Permanent yielding of the piston observed at this stress level

HVOF as a Hard Chrome Replacement



This NAVAIR asset has a replacement cost of \$315,858 and has been collecting dust for three years. Based on stress levels provided by the OEM that designed the gear and the successful AF tests that simulated actual bending stress application in service, the test flying of this EA-6B gear is considered to have minimal risk. It is therefore requested that a flight clearance be issued.

HVOF as a Hard Chrome Replacement

